RESPIRATORY FUNCTION MEASURING SYSTEM AND

APPLICATION THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

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This is a continuation of Application PCT/JP02/01951, filed March 4, 2002, now abandoned.

10   BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a technology for measuring respiratory function, and it particular relates to
15   a measuring system, a measuring apparatus and a measuring method for measuring respiratory function of a subject, an analyzing apparatus, analyzing server, analyzing program for analyzing a measurement result, and a rehabilitation assisting apparatus and a rehabilitation assisting method
20   which can use the measuring system. The measuring system of the present invention is applicable to diagnose respiratory disorders such as SAS (sleep apnea syndrome), ALS (amyotrophic lateral sclerosis), respiratory tract blockage, and/or asthma.

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2. Description of the Related Art

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It is indispensable to recognize a patient's respiratory function accurately to diagnose a patient who suffers with respiratory disorders. Traditionally, the Spirometer has been widely used as an equipment to examine

5　respiratory functions. And with the Spirometer, lung capacity fractions of a patient such as $\dot{V}C$ (vital capacity), ERV (expiratory reserve volume), IRV (inspiratory reserve volume), IC (inspiratory capacity), TV (tidal volume), FRC (functional residual capacity), RV (residual volume), TLC

10　(total lung capacity), as well as a forced expiration curve, FVC (forced vital capacity), FEV1.0 (forced expiratory volume in one second), a flow volume curve, and PEFR (peak expiratory flow rate) are measured and patient's respiratory functions are diagnosed.

15　However, since the Spirometer measures volume or rate of respiration and/or inspiration, data of costal respiration and abdominal respiration cannot be measured independently. A respisomnography is sometimes used to obtain the diagnosis characteristically for thoracic

20　respiration and the abdominal respiration. But, when using the respisomnography, the data are largely effected by the measurement conditions such as how two measuring belts are applied, etc. and the reproducibility of the data is poor, therefore different data are obtained every time even the

25　same subject is measured. For that reason, though a certain diagnosis can be obtained by the respisomnography for

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thoracic respiration and abdominal respiration, it has been

impossible to evaluate the measurement data quantitatively

to produce useful medical views.

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SUMMARY OF THE INVENTION

Therefore, an objective of the present invention is to

provide a technique that enables obtaining highly reliable

10   respiratory waveform data of multiple measurement parts of a

human body. Another object of the present invention is

providing a technology that makes the rehabilitation of

respiratory function more effective utilizing the above-

mentioned measurement technology, and further object is

15   providing a technology to analyze appropriately the data

measured by above-mentioned measurement technology.

An embodiment according to the present invention

relates to a measuring system. This measuring system is a

measuring system for measuring respiratory function

20   characterized in that it includes: a first measuring unit

for detecting volume change of a first measurement part of a

subject sequent to respiratory movement; a second measuring

unit for detecting volume change of a second measurement

part of the subject sequent to respiratory movement; a

25   control unit which acquires an output from said first

measuring unit and said second measuring unit; and an

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analyzing unit which analyzes the output which said control

unit acquires; said first measuring unit and said second

measuring unit respectively include: a sensing unit for

sensing the volume change of the measurement part; and a

5   fixing unit for arranging said sensing unit to the

measurement part; wherein said fixing unit can fix said

sensing unit in a manner of impressing said sensing unit on

the measurement part.

By measuring volume change of the measurement part, a

10   subject's expiration volume and inhalation volume can be

measured. Moreover, since the volume change at the time of

breathing of the first measurement part and the second

measurement part can be measured independently, the state of

thoracic respiration and abdominal respiration is

15   quantitatively acquirable, respectively, for example.

Thereby, the quantitative evaluation about thoracic

respiration and abdominal respiration can be attained though

it used to be impossible conventionally. And the advantage

of this embodiment is tremendously meaningful in the medical

20   field since it enables not only calculating indices of the

rate of abdomen contribution with sufficient accuracy, but

also an important finding may be acquired, for instance,

from the difference in the respiratory waveform of chest and

abdomen.

25   The first measurement part may be near thorax, and

said first measuring unit detects the volume change near

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thorax sequent to costal respiration, and the second

measurement part may be near abdomen, and said second

measuring unit detects the volume change near abdomen

sequent to abdominal respiration.

5　　　Said sensing unit may sense the volume change of the

measurement part from change of pressure applied by said

fixing unit and the measurement part. As the sensing unit

is fixed so that it may press down to the measurement part

by the fixing unit, the sensing unit may be pressed by the

10　measurement part and the fixing unit when the volume of the

measurement part increases. Therefore, the volume change of

the measurement part can be read by change of the pressure

given to the sensing unit.

Said sensing unit may have a bag-like form; said

15　fixing unit may have a belt-like form; and said sensing unit

may be impressed to the measurement part in such a manner

that a body of the subject is wrapped around by said fixing

unit. A harvesting unit which harvest the sensing unit may

be comprised in the fixing unit, and the fixing unit may be

20　wrapped with the body of the subject with the sensing unit

harvested in the harvesting unit.

Said sensing unit may have a cavity inside; said

measuring system may further include a pressure sensor for

measuring air pressure in the cavity; and the volume change

25　of the measurement part may be detected from change of the

air pressure in the cavity. The measuring system may

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further include a pump for sending gas into the cavity. The
measuring system may further include an initial pressure
adjusting unit for adjusting the air pressure in the cavity
to predetermined initial pressure by sending gas into the

5   cavity before a measurement of respiratory function. In
order to measure volume change of the measurement part at
the respiration time correctly, it is desirable to adjust
into the state where a certain amount of pressure is
impressed to the sensing unit also at the time of the

10   maximum expiration. Therefore, gas is sent inside the
sensing unit before measurement of the respiratory function
so that the predetermined initial pressure is set.

Said initial pressure adjusting unit may adjust the
initial pressure within a range where a ratio of the volume

15   change to the change of the air pressure in the cavity is
substantially constant. Said initial pressure adjusting
unit may adjust the initial pressure within a range where a
ratio of the volume change to the change of the air pressure
in the cavity shifts substantially linear. Thereby, the

20   conversion error can be reduced when converting the amount
of atmospheric pressure change into the amount of volume
change.

Said initial pressure adjusting unit may adjust the
initial pressure to be substantially constant when measuring

25   a subject for a plurality of times. Said initial pressure
adjusting unit may adjust the initial pressure to be

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substantially constant when measuring a plurality of

subjects. Thereby, since the conditions at the time of

measurement can be kept constant, a measurement error can be

reduced and the measurement data of good reproducibility can

5   be obtained.

The measuring system may further include an indicating

unit which indicates suitable respiratory movement to a

subject according to the kind of data which should be

measured. Timing may be planned with monitoring the

10   subject's respiratory waveform, and directions may be taken

out to the subject. Since anyone can measure the

respiration function appropriately even if there is no

assistance of a doctor and/or an assistant etc., a subject

himself/herself can perform measurement at home, and the

15   measurement can be performed even in a doctor-less village

in an isolated island or a depopulated area, etc.

The measuring system may further include a condition

input unit which receives an input of information about a

measurement condition. The measuring system may further

20   include a measurement control unit which controls said

initial pressure adjusting unit or said indicating unit

based on the measurement condition.

Said measurement control unit may determine the

initial pressure which said initial pressure adjusting unit

25   adjusts based on the measurement condition. For example,

initial pressure may be changed by a male or by a woman, and

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also initial pressure may be changed by a subject who has a
respiratory disease or by a healthy person. Initial
pressure may be changed according to a subject's size of the
chest, waist, and/or the corpulence degree, etc.; further
5 initial pressure may be changed according to a subject's
respiratory function.

Said measurement control unit may determine a content
which said indicating unit indicates to a subject based on
the measurement condition. For example, the direction
10 content may be changed according to a subject's anamnesis.

The measuring system may further include a waveform
generating unit for generating respiratory waveform data
which shows respiratory state of a subject from the volume
change near thorax which the first measuring unit detects,
15 and the volume change near diaphragm which the second
measuring unit detects. Said waveform generating unit may
weight the volume change near thorax and the volume change
near diaphragm with a predetermined ratio when generating
the respiratory waveform data. Also the ratio with which
20 volume change is edited may be determined according to the
personal information, such as the abdomen contribution
percentage, sex of the subject, and anamnesis of the subject,
etc.

The measuring system may further include a calculating
25 unit for calculating at least one respiratory function
barometer among a lung capacity fraction, a forced

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expiratory curve, a forced lung capacity, a forced
expiratory volume in one second, a forced expiratory rate in
one second, a maximum mid-expiratory flow, a maximum
ventilation volume, a flow volume curve, a peak expiratory
5　flow rate, and a rate of abdomen contribution based on at
least one of the volume change near thorax, the volume
change near diaphragm and the respiratory waveform data.
Said calculating unit may calculate the respiratory function
barometer, converting at least one of the volume change near
10　thorax, the volume change near diaphragm, and the
respiratory waveform data into respiratory volume.

　　　The measuring system may further include a waveform
characteristic extracting unit which extracts a feature of
waveform from at least one of the volume change near thorax,
15　the volume change near diaphragm, and the respiratory
waveform data. The feature of a differential function, a
secondary differential function, and/or a third differential
function and the like of each waveform may be extracted. The
feature may be extracted by comparing with each waveform.

20　　　The measuring system may further include a respiratory
tract state judging unit which judges state of constriction
or blockage of a respiratory tract with reference to the
respiratory waveform data, the forced expiration curve, or
the flow volume curve. Said respiratory tract state judging
25　unit may judge that a respiratory tract of a subject is
constricted or blocked in the case where the respiratory

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waveform data, the forced expiratory curve, or the flow

volume curve has a waveform showing an increase of the air

pressure in the cavity when the subject starts expiration.

Although the waveform which shows the atmospheric pressure

5   in a cavity decreases in connection with the expiration is

measured in the case of a healthy person who does not have a

constriction in a respiratory tract, the phenomenon which

·the atmospheric pressure, i.e., the chest data, or abdomen

data tends to increase according to factors, such as

10   restriction of the air current in the constriction portion

at the time of the expiration or the abnormal movement of

the respiratory muscle at the time of the expiration, has

been observed by this inventor. Since such a phenomenon is

characteristically seen for an asthmatic patient who has the

15   condition of a respiratory tract constriction, the

measurement result is useful to diagnose the respiratory

tract constriction. Said respiratory tract state judging

unit may judge a degree of constriction or blockage of the

respiratory tract based on an aspect of increasing of the

20   air pressure.

The measuring system may further include a database

which stores a medical view correspondent with at least one

of a feature of the waveform of the respiratory waveform

data, a feature of the waveform of the volume change near

25   thorax, a feature of the waveform of the volume change near

diaphragm, a difference of the waveform between the volume

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change near thorax and the volume change near diaphragm, a
respiratory function barometer, and a personal data of a
subject.

The measuring system may further include a database
5 referring unit which acquires the medical view for the
subject with reference to said database. The measuring
system may further include a display unit which displays the
medical view.

Another embodiment according to the present invention
10 relates to a measuring apparatus. This measuring apparatus
is a measuring apparatus for measuring respiratory function
characterized in that it includes: a sensing unit for
sensing volume change of a measurement part of a subject
sequent to respiratory movement; and a fixing unit for
15 arranging said sensing unit near the measurement part;
wherein said fixing unit has a belt-like form and can fix
said sensing unit in a manner of impressing said sensing
unit on the measurement part; and said sensing unit senses
the volume change of the measurement part from change of
20 pressure applied by said fixing unit and the measurement
part.

Still another embodiment according to the present
invention also relates to a measuring apparatus. This
measuring apparatus is a measuring apparatus for measuring
25 respiratory function characterized in that it includes: a
first measuring unit for detecting volume change of a first

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measurement part of a subject sequent to respiratory

movement; and a second measuring unit for detecting volume

change of a second measurement part of the subject sequent

to respiratory movement; said first measuring unit and said

5　second measuring unit respectively include: a sensing unit

for sensing the volume change of the measurement part; and a

fixing unit for arranging said sensing unit near the

measurement part; wherein said fixing unit has a belt-like

form and can fix said sensing unit in a manner of impressing

10　said sensing unit on the measurement part; and said sensing

unit senses the volume change of the measurement part from

change of pressure applied by said fixing unit and the

measurement part.

Said sensing unit may have a cavity inside and

15　includes a first connecting unit for sending gas which is in

the cavity to a pressure sensor for measuring air pressure

in the cavity. Said sensing unit may further include a

second connecting unit for connecting with a pump for

sending gas into the cavity. The first connecting unit and

20　the second connecting unit may be a tube formed by a rubber,

a resin, or the like.

The measuring apparatus may further include a control

unit which includes said pressure sensor and said pump.

Said control unit may further include a recording unit which

25　records the air pressure in the cavity which said pressure

sensor measures. Said recording unit may record the air

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pressure in the cavity, or data converted from the air

pressure into the volume or respiratory volume in an

external recording medium.

　　　Said control unit may further include a transfer unit

5　which transfers the air pressure in the cavity which said

pressure sensor measures to an analyzing apparatus for

analyzing respiratory function.　The transfer unit may

transfer the data using arbitrary communicating means of a

cable or a radio, such as the internet, a cellar-phone

10　network, or infrared ray.

　　　The measuring apparatus may further include an initial

pressure adjusting unit for adjusting the air pressure in

the cavity to predetermined initial pressure by sending gas

into the cavity before a measurement of respiratory function.

15　Said initial pressure adjusting unit may adjust the initial

pressure within a range where a ratio of the volume change

to the change of the air pressure in the cavity is

substantially constant.　Said initial pressure adjusting

unit may adjust the initial pressure within a range where a

20　ratio of the volume change to the change of the air pressure

in the cavity shifts substantially linear.　Said initial

pressure adjusting unit may adjust the initial pressure to

be substantially constant when measuring a subject for a

plurality of times.　Said initial pressure adjusting unit

25　may adjust the initial pressure to be substantially constant

when measuring a plurality of subjects.

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　　　Still another embodiment according to the present invention relates to an analyzing apparatus. This analyzing apparatus is an analyzing apparatus for analyzing respiratory function of a subject characterized in that it

5　includes: a measurement data acquiring unit which acquires respiratory function measurement data of the subject; and a calculating unit for calculating at least one respiratory function barometer among a lung capacity fraction, a forced expiratory curve, a forced lung capacity, a forced

10　expiratory volume in one second, a forced expiratory rate in one second, a maximum mid-expiratory flow, a maximum ventilation volume, a flow volume curve, a peak expiratory flow rate, and a rate of abdomen contribution.

　　　The respiratory function measurement data may include

15　chest data acquired by measurement of volume change near thorax and abdomen data acquired by measurement of volume change near diaphragm; and said analyzing apparatus may further include a waveform generating unit which generates respiratory waveform data which shows respiratory state of a

20　subject from the chest data and the abdomen data. Said waveform generating unit may weight the chest data near thorax and the abdomen data with a predetermined ratio when generating the respiratory waveform data.

　　　The analyzing apparatus may further include a waveform

25　characteristic extracting unit which extracts a feature of waveform from at least one of the volume change near thorax,

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the volume change near diaphragm, and the respiratory

waveform data. The analyzing apparatus may further include

a respiratory tract state judging unit which judges state of

constriction or blockage of a respiratory tract with

5   reference to the respiratory waveform data, the forced

expiration curve, or the flow volume curve. Said

respiratory tract state judging unit may judge that a

respiratory tract of a subject is constricted or blocked in

the case where the respiratory waveform data, the forced

10 expiratory curve, or the flow volume curve has a waveform

showing an increase of the chest data or the abdomen data of

the subject when the subject starts expiration. Said

respiratory tract state judging unit may judge a degree of

constriction or blockage of the respiratory tract based on

15 an aspect of increasing of the chest data or the abdomen

data. The analyzing apparatus may further include a

database referring unit which acquires a medical view for a

subject with reference to a database which stores the

medical view correspondent with at least one of a feature of

20 the waveform of the respiratory waveform data, a feature of

the waveform of the volume change near thorax, a feature of

the waveform of the volume change near diaphragm, a

difference of the waveform between the volume change near

thorax and the volume change near diaphragm, a respiratory

25 function barometer, and a personal data of the subject.

　　Still another embodiment according to the present

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invention relates to a computer program. This program makes a computer realize: a function of acquiring respiratory function measurement data of a subject; and a function of calculating at least one respiratory function barometer

5　among a lung capacity fraction, a forced expiratory curve, a forced lung capacity, a forced expiratory volume in one second, a forced expiratory rate in one second, a maximum mid-expiratory flow, a maximum ventilation volume, a flow volume curve, a peak expiratory flow rate, and a rate of

10　abdomen contribution.

The respiratory function measurement data may include chest data acquired by measurement of volume change near thorax and abdomen data acquired by measurement of volume change near diaphragm; and the program may further make a

15　computer realize a function of generating respiratory waveform data which shows respiratory state of a subject from the chest data and the abdomen data. The program may further make a computer realize a function of weighting the chest data near thorax and the abdomen data with a

20　predetermined ratio when generating the respiratory waveform data.

The program may further make a computer realize a function of extracting a feature of waveform from at least one of the volume change near thorax, the volume change near

25　diaphragm, and the respiratory waveform data. The program may further make a computer realize a function of judging

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state of constriction or blockage of a respiratory tract

with reference to the respiratory waveform data, the forced

expiration curve, or the flow volume curve. The program may

judge that a respiratory tract of a subject is constricted

5   or blocked in the case where the respiratory waveform data,

the forced expiratory curve, or the flow volume curve has a

waveform showing an increase of the chest data or the

abdomen data of the subject when the subject starts

expiration. The program may judge a degree of constriction

10   or blockage of the respiratory tract based on an aspect of

increasing of the chest data or the abdomen data. The

program may further make a computer realize a function of

acquiring a medical view for a subject with reference to a

database which stores the medical view correspondent with at

15   least one of a feature of the waveform of the respiratory

waveform data, a feature of the waveform of the volume

change near thorax, a feature of the waveform of the volume

change near diaphragm, a difference of the waveform between

the volume change near thorax and the volume change near

20   diaphragm, a respiratory function barometer, and a personal

data of the subject.

Still another embodiment according to the present

invention relates to an analyzing server. This analyzing

server is an analyzing server for analyzing respiratory

25   function of a subject characterized in that it comprises: a

database stored respiratory function measurement data and a

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medical view correspondingly; a receiving unit which
receives a requirement of referring said database through a
network; a measurement data acquiring unit which acquires
the respiratory function measurement data of the subject; a

5   database referring unit which acquires the medical view with
reference to said database based on the respiratory function
measurement data; and a transmitting unit which transmits
the medical view through the network.

This analyzing server provides the database for leading a

10 medical view from the data measured by above-mentioned
measuring apparatus. The medical view can be acquired by
accessing the analyzing server with a terminal of hospital,
a clinic, and a rehabilitation facility, for example, and
sending the respiratory function measurement data of the

15 subject to the analyzing server. A business model can work
out where the database is managed by the analyzing server
400 in the block without placing them at each terminal, and
a user using the database is charged.

The respiratory function measurement data may include

20 chest data acquired by measurement of volume change near
thorax and abdomen data acquired by measurement of volume
change near diaphragm. The respiratory function measurement
data may be respiratory waveform data generated using the
chest data and the abdomen data. The respiratory waveform

25 data may be generated by weighting the chest data and the
abdomen data with a predetermined ratio.

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Still another embodiment according to the present
invention relates to a rehabilitation assisting apparatus.
This rehabilitation assisting apparatus is a rehabilitation
assisting apparatus which assists rehabilitation of

5   respiratory function characterized in that it comprises: a
pressurizing unit which includes a pressurizing member for
squeezing a body of a subject; and a fixing unit for
arranging said pressurizing unit to the body of the subject;
wherein said fixing unit has a bag-like form and can fix

10   said pressurizing unit in a manner of impressing said
pressurizing unit on the body; and said pressurizing unit
has a belt-like form and squeezes the body with increasing
volume thereof by introducing gas therein.

　　　Said pressurizing member may be fixed so that said

15   pressurizing unit squeezes an expectoration part of the
subject.　Said pressurizing unit may have a plurality of
said pressurizing members; and said rehabilitation assisting
apparatus may further comprise a control unit which controls
volume of gas inside said pressurizing members so that said

20   pressurizing members squeeze the expectoration part.　This
performs the technique generally called "squeezing."　As for
rehabilitation, arbitrary rehabilitations such as breathing
under pressurization load, and/or a exercise such as a walk,
etc., may be carried out.

25   　　　The rehabilitation assisting apparatus may comprise a
plurality of said pressurizing units; and said pressurizing

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units may be arranged at least near thorax and near diaphragm of the subject. The rehabilitation assisting apparatus may further comprise a pressure sensor which measures air pressure inside said pressurizing member; and

5 respiratory state of the subject may be measured by sensing the volume change near thorax or diaphragm from change of the air pressure measured by said pressure sensor. Thereby, the state of thoracic respiration and abdominal respiration can be independently measured like above-stated measurement

10 equipment. Moreover, the respiratory function can be continuously measured after the rehabilitation, without removing the pressurization units. Thus, this rehabilitation assisting apparatus has function of both the pressurization of the expectoration part and the function of

15 respiratory measurement at the time of rehabilitation.

Still another embodiment according to the present invention relates to a measuring method. This method is a method of measuring respiratory function characterized in that it includes: a step of fixing a first measuring unit

20 which includes a first sensing unit for sensing volume change of a first measurement part of a subject sequent to respiratory movement; and a first fixing unit for arranging said first sensing unit to the first measurement part, in such a manner that said first fixing unit pinches said first

25 sensing unit between said first fixing unit and the first measurement part; a step of fixing a second measuring unit

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which includes a second sensing unit for sensing volume

change of a second measurement part of the subject sequent

to respiratory movement; and a second fixing unit for

arranging said second sensing unit to the second measurement

5   part, in such a manner that said second fixing unit pinches

said second sensing unit between said second fixing unit and

the second measurement part; a step of measuring

simultaneously the volume change of the first measurement

part sensed by said first sensing unit and the volume change

10   of the second measurement part sensed by said second sensing

unit.

The first measurement part may be near thorax and the

second measurement part may be near diaphragm. Said first

fixing unit and said second fixing unit may have belt-like

15   forms; said first sensing unit and said second sensing unit

may have bag-like forms; said step of fixing may fix said

first fixing unit and said second fixing unit in such a

manner that a body of the subject is wrapped around by said

first fixing unit and said second fixing unit; and said step

20   of measuring may measure the volume change by sensing air

pressure inside said first sensing unit and said second

sensing unit.

The method may further include, between said step of

fixing and said step of measuring, a step of adjusting the

25   air pressure inside said sensing unit to predetermined

initial pressure by sending gas into said sensing unit; and

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said step of measuring may measure maintaining an amount of
gas introduced into said sensing unit in said adjusting.
The valve etc. may be prepared in each sensing unit so that
the gas sent inside of the sensing unit may not leak out to
5　the outside. Thereby, it can prevent the condition change
during the measurement.

Still another embodiment according to the present
invention relates to a rehabilitation assisting method.
This method is a method of assisting rehabilitation of
10　respiratory function characterized in that it includes: a
step of equipping a subject with a pressurizing unit which
comprises a pressurizing member for squeezing a body of the
subject and a fixing unit for arranging the pressurizing
unit to the body; a step of squeezing the body of the
15　subject by the pressurizing member; a rehabilitation step of
making the subject perform respiratory movement under
squeezing; a first measurement step of measuring respiratory
state of the subject by sensing pressure applied to the
pressurizing member while said rehabilitation step.

20　The fixing unit may have a belt-like form; the
pressurizing member may have a bag-like form; said step of
equipping may fix the pressurizing unit in such a manner
that the pressurizing member is pinched between the fixing
unit and the body of the subject; said step of squeezing may
25　squeeze the body with increasing volume of the pressurizing
unit by introducing gas into the pressurizing unit.

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Said step of equipping may equip the subject with the
pressurizing unit so that the pressurizing unit squeezes an
expectoration part of the subject; said step of squeezing
may squeeze the expectoration part by adjusting air pressure
5   inside the pressurizing unit.

The method may include after said rehabilitation step:
a step of adjusting air pressure inside the pressurizing
unit to predetermined pressure; a second measurement step of
measuring respiratory state of the subject after
10   rehabilitation by sensing the air pressure inside the
pressurizing unit.

The method may further include a step of evaluating
appropriate value of pressurizing to squeeze the body in
said rehabilitation step based on the respiratory state of
15   the subject measured in said first measurement step.
Thereby, during the rehabilitation, the subject's
respiratory condition can be monitored, and suitable
pressurization can be applied.

The method may further include a step of evaluating
20   effect of said rehabilitation step based on the respiratory
state of the subject measured in said second measurement
step. Since the subject's respiratory condition can be
monitored immediately after starting of the rehabilitation,
it is suitable for measuring the change of the respiratory
25   state with the passage of time after the subject starts
rehabilitation.

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It is to be noted that any arbitrary combination of the above-described structural components, and expressions changed between a method, an apparatus, a system, a recording medium, a computer program and so forth are all

5　effective and encompassed by the present embodiments.

Moreover, this summary of the invention does not necessarily describe all necessary features so that the invention may also be sub-combination of these described features.

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BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a figure showing a composition of a

15　measuring system according to an embodiment.

Fig. 2A and 2Bare figures schematically showing an appearance of a measuring unit.

Fig. 3 is a figure showing how a subject is equipped with the measuring unit.

20　Fig. 4A, 4B, and 4C are figures showing cross sections of a part equipped with the measuring unit.

Fig. 5 is a figure showing other example of a fixing unit.

Fig. 6 is a figure schematically showing an appearance

25　of a control unit.

Fig. 7 is a flow chart which shows procedures of

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measuring respiratory function using the measuring system of
the embodiment.

Fig. 8 is a flow chart which shows procedures of
analyzing the respiratory function using the measuring
5　system of the embodiment.

Fig. 9 is a figure showing personal information of
subjects who went through a respiratory function inspection
using the measuring system of the embodiment.

Fig. 10 is a figure showing change of inner pressure
10　of a sensing unit with passage of time when measuring the
lung volume fraction of a healthy person as the subject
using the measuring system of the embodiment.

Fig. 11A and 11B are figures showing measurement
results of the vital capacity of healthy persons as the
15　subject using the measuring system of the embodiment and the
Spirometer.

Fig. 12A and 12B are figures showing measurement
results of the expiratory reserve volume of healthy persons
as the subject using the measuring system of the embodiment
20　and the Spirometer.

Fig. 13A and 13B are figures showing measurement
results of the inspiratory reserve volume of healthy persons
as the subject using the measuring system of the embodiment
and the Spirometer.

25　Fig. 14A and 14B are figures showing measurement
results of the inspiratory capacity of healthy persons as

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the subject using the measuring system of the embodiment and

the Spirometer.

Fig. 15A and 15B are figures showing measurement

results of the tidal volume of healthy persons as the

5　subject using the measuring system of the embodiment and the

Spirometer.

Fig. 16 is a figure showing change of inner pressure

of a sensing unit with passage of time when measuring the

forced expiratory curve of a healthy person as the subject

10　using the measuring system of the embodiment.

Fig. 17A, 17B and 17C are figures showing the flow

volume curve of a healthy person as the subject measured by

the measuring system of the embodiment.

Fig. 18A and 18B are figures showing measurement

15　results of the forced expiratory capacity of healthy persons

as the subject using the measuring system of the embodiment

and the Spirometer.

Fig. 19A and 19B are figures showing measurement

results of the forced expiratory volume in one second of

20　healthy persons as the subject using the measuring system of

the embodiment and the Spirometer.

Fig. 20A and 20B are figures showing measurement

results of the peak expiratory flow rate of healthy persons

as the subject using the measuring system of the embodiment

25　and the Spirometer.

Fig. 21 is a figure showing changes of inner pressure

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of a sensing unit with passage of time when measuring the
ventilation volume at resting of a healthy person as the
subject using the measuring system of the embodiment.

　　　Fig. 22A and 22B are figures showing measurement
5　results of the minutes volume of healthy persons as the
subject using the measuring system of the embodiment and the
Spirometer.

　　　Fig. 23A and 23B are figures showing measurement
results of the tidal volume of healthy persons as the
10　subject using the measuring system of the embodiment and the
Spirometer.

　　　Fig. 24A and 24B are figures showing measurement
results of the peak interval of waveform of healthy persons
as the subject using the measuring system of the embodiment
15　and the Spirometer.

　　　Fig. 25 is a figure showing a relation between the
chest data and the abdomen data when measuring the
ventilation volume at resting of a healthy person as the
subject using the measuring system of the embodiment.

20　　　Fig. 26 is a figure showing a relation between the
chest data and the abdomen data when measuring the forced
expiratory curve of a healthy person as the subject using
the measuring system of the embodiment.

　　　Fig. 27A and 27B are figures showing measurement
25　results of the vital capacity of patients who have
respiratory disease as the subject using the measuring

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system of the embodiment and the Spirometer.

Fig. 28A and 28B are figures showing measurement results of the expiratory reserve volume of patients who have respiratory disease as the subject using the measuring

5   system of the embodiment and the Spirometer.

Fig. 29A and 29B are figures showing measurement results of the inspiratory reserve volume of patients who have respiratory disease as the subject using the measuring system of the embodiment and the Spirometer.

10   Fig. 30A and 30B are figures showing measurement results of the inspiratory capacity of patients who have respiratory disease as the subject using the measuring system of the embodiment and the Spirometer.

Fig. 31A and 31B are figures showing measurement

15   results of the tidal volume of patients who have respiratory disease as the subject using the measuring system of the embodiment and the Spirometer.

Fig. 32A and 32B are figures showing measurement results of the forced expiratory capacity of patients who

20   have respiratory disease as the subject using the measuring system of the embodiment and the Spirometer.

Fig. 33A and 33B are figures showing measurement results of the peak expiratory flow rate of patients who have respiratory disease as the subject using the measuring

25   system of the embodiment and the Spirometer.

Fig. 34A and 34B are figures showing measurement

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results of the minutes volume of patients who have

respiratory disease as the subject using the measuring

system of the embodiment and the Spirometer.

Fig. 35A and 35B are figures showing measurement

5　results of the tidal volume of patients who have respiratory

disease as the subject using the measuring system of the

embodiment and the Spirometer.

Fig. 36A and 36B are figures showing measurement

results of the peak interval of waveform of patients who

10　have respiratory disease as the subject using the measuring

system of the embodiment and the Spirometer.

Fig. 37 is a figure showing change of inner pressure

of a sensing unit with passage of time when measuring the

forced expiratory curve of a patient who has respiratory

15　disease as the subject using the measuring system of the

embodiment.

Fig. 38 is a figure showing the flow volume curve of a

patient who has respiratory disease as the subject measured

by the measuring system of the embodiment.

20　Fig. 39 is a figure showing a relation between the

value of rising of pressure inside the sensing unit and the

peak expiratory flow rate at forced expiration.

Fig. 40 is a figure showing a structure of an

analyzing server according to the embodiment and a terminal

25　which accesses the analyzing server.

Fig. 41A, 41B, 41C, 41D, and 41E are the figures

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showing samples of usage of a rehabilitation assisting

apparatus according to the embodiment.

   Fig. 42 is a flow chart which shows a rehabilitation

assisting method according to the embodiment.

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DETAILED DESCRIPTION OF THE INVENTION

   Fig. 1 is a composition figure of the measuring system

10 according to an embodiment of the present invention. The

10 measuring system 10 mainly includes a measuring apparatus 50

equipping with a measuring unit 100 for measuring a

subject's respiratory condition and a control unit 200 which

acquires an output from the measuring unit 100, and an

analyzing unit 300 for analyzing the output which the

15 control unit 200 acquires. In Fig. 1, the part of

composition of the control unit 200 and the analysis unit

300 are usually realized by CPU of arbitrary computers, the

memory, and the program loaded in the memory, explaining it

as the hardware component, for example, but here the

20 functional block which is realized with those combination is

described. Therefore, it will be understood by the pertinent

business people that these functional blocks can be realized

independently in the hardware, independently with the

software or in various forms depending on the combination

25 form.

   The measuring unit 100 includes a costal respiration

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measuring unit 100a for measuring a volume change near

thorax as an example of a first measuring unit and an

abdominal respiration measuring unit 100b for measuring a

volume change near the diaphragm as an example of a second

5   measuring unit. The costal respiration measuring unit 100a

and the abdominal respiration measuring unit 100b detect the

volume changes of the measurement parts by changes of the

atmospheric pressure inside a sensing unit, respectively.

Thereby, the measuring system 10 of the present embodiment

10   can measure the data corresponding to the costal respiration

and the data corresponding to the abdominal respiration

independently. Moreover, reproducibility is good and it is

a big merit that reliable data is obtained also

quantitatively.

15   Fig. 2A and 2B schematically show the appearance of

the measuring unit 100. Fig. 2A is a figure seeing the

measuring unit 100 from the side which touches a subject's

body and the Fig. 2B is a figure seeing the measuring unit

100 from the reverse-side. The measuring unit 100 includes

20   the sensing unit 110 for detecting a volume change of the

measurement part accompanying respiratory action of a

subject, and a fixing member 120 for arranging the sensing

unit 110 near the measurement part. The sensing unit 110

has a bag-like form with a cave inside, and detects a volume

25   change of the measurement part with change of the

atmospheric pressure inside. The sensing unit 110 is

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equipped with the tube 114 for sending gas inside from the
pressure pump 220 as an example of a first connection member
and a tube 112 for sending gas to a pressure gauge as an
example of a second connection member. The sensing unit 110

5　is contained in the case 116 made in the fixing member 120.

The fixing member 120 has a belt-like form and is
wrapped around the subject's body, arranging the sensing
unit 110 to the measurement part. Soft Materials, such as
soft cloth, may be used for the fixing member 120 so that it

10　may be easily wrapped around the subject's body. Moreover,
the material with little elasticity, such as canvas cloth,
may be used so that it may not expand greatly by respiratory
motion of a subject. The adhesion members 122a and 122b for
attaching both ends of the fixing member 120, when the

15　fixing member 120 is wrapped around the subject's body, are
formed in the fixing member 120. The adhesion members 122a
and 122b may be a zipper or a plane fastener, etc.

Fig. 3 shows how the subject is equipped with the
costal respiration measuring unit 100a and the abdominal

20　respiration measuring unit 100b. The costal respiration
measuring unit 100a is equipped around the subject's chest.
The abdominal respiration measuring unit 100b is equipped
around subject's diaphragm. When equipping a subject with
the measuring unit 100, the sensing unit 110 is first stuck

25　to the measurement part, and the fixing member is wrapped
around the subject's body firmly. Since there is sometimes

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a right-and-left difference in muscular power of the
respiratory muscles, the position of the sensing unit 110
may be determined considering the subject's dominant hand.
For example, the position in which the sensing unit 110 is
5   fixed may be unified to be the dominant hand side or the
contrary side of the subject. The position in which the
sensing unit 110 is fixed may be unified to be the subject's
left half or right half of the body.

Fig. 4A, 4B, and 4C show cross sections of a subject
10   equipped with the measuring unit 100. Fig. 4A shows a
situation when an initial pressurization is performed by
sending gas inside the sensing unit 110 from the
pressurization pump 220 after the subject is equipped with
the measuring unit 100. The Gas is sent into the inside of
15   the sensing unit 110, and empty space is made between the
fixing member 120 and the measurement part. Since it is
necessary to change into the state where a certain amount of
pressure is impressed to the sensing unit also at the time
of the maximum inspiration in order to measure the volume
20   change of the measurement part correctly at the time of
inspiration, the initial pressurization is set in this way.
Moreover, it is meaningful for keeping measurement
conditions constant by standardizing an initial
pressurization value. Fig. 4B shows a situation when a
25   subject performs inspiration action. When a subject inhales
air, the volume near the thorax and the diaphragm of the

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subject increase, then, the sensing unit 110 is compressed

between the subject's body and the fixing member, therefore

internal atmospheric pressure becomes high. Fig. 4C shows a

situation when the subject performs expiration action. When

5 the subject exhales, the atmospheric pressure inside the

sensing unit 110 becomes low because the volume near thorax

and diaphragm of the subject may decrease, and empty space

between the subject's body and the fixing member spreads out.

Thus, the volume change near thorax and diaphragm can be

10 detected with the change of inner pressure of the sensing

unit 110.

When using this measuring system as rehabilitation

assisting apparatus, the sensing unit 110 can function as a

pressurization part. Namely, a subject's body is pressed

15 with the predetermined load by sending gas inside of the

sensing unit 110, and making the volume of the sensing unit

110 increase. A subject is able to perform rehabilitation

while breathing under load. At this time, the measuring

unit 100 may be equipped pressing the expectoration part of

20 a subject by the sensing unit 110, and the rehabilitation is

performed using the squeezing method.

Fig. 5 shows another example of the fixing member 120.

In the example of Fig. 5, a hook 124 is formed at one end of

the fixing member 120, which lets another end of the fixing

25 member 120 pass through. At the time of wearing, another

end is passed through the hook 124, and fix the adhesion

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member 122 after pulling the end fully to make it stick. The

adhesion member 122 may be a zipper or a plane fastener, etc.

According to the measuring unit 100 shown in Fig. 5, even if

it is the case when a subject itself equips with the

5   measuring unit 100, the measuring unit 100 can be fixed

appropriately and easily.

Now, going back to Fig. 1 and the explanation of the

control unit 200 and the analyzing unit 300 is continued.

The control unit 200 includes an initial pressure adjusting

10   unit 210, a pressurization pump 220, a pressure gauge 230, a

recording unit 240, the measurement control unit 250, a

indicating unit 260, a display unit 270, a transfer unit 280,

and a condition input unit 290.

The initial pressure adjusting unit 210 controls the

15   pressurization pump 220 to send gas inside of the sensing

unit 110 and adjust the pressure to the predetermined

initial value before measurement of the respiratory function.

The initial pressure may be set up within the range in which

the ratio between the volume change of the measurement part

20   and the pressure change in the sensing unit 110 are

approximately same, or may be set up within the range in

which the ratio between the volume change of the measurement

part and the pressure change in the sensing unit 110 is

linear. If the initial pressure is too large, a burden will

25   be given to a subject and there is a possibility that a

respiratory state cannot be measured correctly. If the

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initial pressure is too small, there is a possibility that
the pressure change in the sensing unit 110 may not follow
accordingly to the volume change of the measurement part.
What is necessary is just to adjust the initial pressure to
5   the range in which the pressure change in the sensing unit
110 can be converted properly to the volume change of the
measurement part, or respiratory volume at the time of
breathing.

        The initial pressure adjusting unit 210 may adjust the
10   initial pressure to the constant value when measuring a
subject for multiple times. With this, the measurement
conditions can be maintained constantly for multiple
measurements of the same subject, and the measurement
results can be compared with each other and examined
15   quantitatively. The initial pressure adjusting unit 210 may
adjust the initial pressure to the constant value when
measuring multiple subjects. Thereby, the measurement
conditions can be kept constant and the measurement results
can be compared with each other and examined quantitatively.
20   Thus, since conditions can be unified when measuring by the
initial pressure adjusting unit 210, the data obtained are
with high reproducibility and reliable. The initial
pressure may be determined based on a subject's sex, the
rate of body fat, a chest circumference, a waist, an
25   anamnesis, a lung capacity, the size of the sensing unit 110,
or the like.

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After the initial pressure adjusting unit 210 sends
gas into the sensing unit 110, the measurement is performed
maintaining the quantity of the gas inside the sensing unit
110. Thereby, the conditions can be kept constant while the
5　measurement is performed. A valve may be attached to the
sensing unit 110, so that gas once sent in would not flow
outside.

The pressurization pump 220 sends gas inside the
sensing unit 110, so that the pressure in the sensing unit
10　110 may become predetermined initial pressure. In the case
of using this system as rehabilitation assisting apparatus,
gas is sent inside of the sensing unit 110 by the
pressurization pump 220 until it becomes predetermined load
pressure.

15　The pressure gauge 230 as an example of the pressure
sensor measures the atmospheric pressure inside the sensing
unit 110. Arbitrary known pressure gauge or pressure sensor
may be used as the pressure gauge 230. In the present
embodiment, a pressure sensor that converts the pressure
20　into a voltage signal by PIEZO resistive element is used.

The recording unit 240 samples the measurement data
which the pressure gauge 230 measures in a predetermined
sampling frequency, and records them as the respiratory
waveform data. The recording unit 240 may record the
25　measurement data in a memory inside the control unit 200,
and/or may record them in a recording media, such as a

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floppy disk, CD-ROM, MO, and the like. Moreover, the
recording unit 240 may not be comprised, and the measurement
data may be transmitted directly to the analyzing unit 300.
In the present embodiment, the voltage signals which the
5　pressure gauge 230 measures are recorded in the memory
inside the recording unit 240, and are transmitted to the
analyzing unit 300 by the transfer unit 280. The voltage
signals may be converted into a digital signal with A/D
converter if necessary. Moreover, the voltage signals may
10　be converted into pressure values and recorded or otherwise
may be recorded after converting them into respiratory
volume or respiration rate using a predetermined conversion
formula.

The condition input unit 290 receives the information
15　concerning measurement conditions from a subject or a
measurer. For example, the condition input unit 290 may
receive information, such as the kind of data which should
be measured, a subject's sex, age, height, weight, chest
circumference, waist size, a rate of body fat, and private
20　information like about anamneses, measurement day, the
number of times of measurement, temperature, atmospheric
pressure, and humidity, etc. The information may be
recorded by recording unit 240 together with measurement
data and/or may be used for control of the measurement
25　control unit 250 or analysis of the analyzing unit 300, if
necessary.

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     The measurement control unit 250 controls at least one of the initial pressure adjusting unit 210, the pressurization pump 220, the recording unit 240, and the indicating unit 260 to perform the measurement according to

5   the kind of data which should be measured. The measurement control unit 250 may have a table for determining contents, procedure , or the like of the measurement based on the conditions which the condition input unit 290 receives. For example, a subject's sex and initial pressure may be stored

10   correspondingly in the table, or the kind of data which should be measured and the sampling frequency of the data at the time of recording may be stored correspondingly in the table. And, the measurement may be controlled referring this table.

15   Moreover, the measurement procedure suitable for the kind of data which should be measured may be indicated to a subject through the indicating unit 260. At this time, the contents of directions may be determined based on the measurement conditions which is received by the condition

20   input unit 290. For example, when the forced vital capacity FVC is measured, the indicating unit 260 may indicate to a subject while monitoring the measurement values by the pressure gauge 230, to make the subject breathe in until reaching the maximum inspiration level, saying "Please

25   continue inhaling until it becomes impossible to breathe", until the measurement value is stabilized at the constant

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value, and saying "Please breathe out at a one stretch",

when it is judged that the measurement value is stabilized

at the constant value. Thus, a suitable measurement

procedure is given to a subject while the subject's

5　respiratory condition is being observed. In order a

suitable measurement is performed, the respiratory waveform

used as a standard may be stored, and a timing of issuing

the direction to the subject may be planned comparing the

standard waveform to the subject's respiratory waveform.

10　　　　When using this measuring system 10 as the

rehabilitation assisting apparatus, the measurement control

unit 250 may control a rehabilitation program. The

rehabilitation programs may be saved beforehand in the

measurement control unit 250, and may be chosen based on the

15　conditions received by the condition input unit 290, and/or

a rehabilitation program may be inputted by the condition

input unit 290. At this time, the procedure of the

rehabilitation may be indicated to a patient by the

indicating unit 260. For example, when a patient requires

20　the respiratory rehabilitation under pressurization, the

patient receives pressure to the predetermined point with

the pressurization pump 220, and performs rehabilitation of

breathing for predetermined time under pressurization.

　　　　The indicating unit 260 indicates suitable respiratory

25　operations to a subject according to the kind of data which

should be measured. The indicating unit 260 may output the

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directions transmitted from the measurement control unit 250
to a subject, or may judge the necessary directions.
Directions may be outputted by the display unit 270 as
visual information, and/or may be outputted as sound
5　information with a speaker etc.

The display unit 270 displays information such as the
measured value by the pressure gauge 230, and classification
of the data at a time of measuring. The display unit 270
may be used as an interface when receiving information from
10　a measurer by the condition input unit 290.

The transfer unit 280 transfers the measured data to
the analyzing unit 300. The transfer unit 280 may transfer
measurement data to the analyzing unit 300 through the cable
which connects the control unit 200 and the analyzing unit
15　300, and/or may transfer it using the communication means of
cables, such as the telephone network, the cellular-phone
network, the Internet, infrared rays, and the radio wave, or
wireless radio. When the recording unit 240 records data in
a recording medium, the transfer unit 280 may be not
20　necessary since the data are sent to the analyzing unit 300
through the recording medium.

The analyzing unit 300 includes a measurement data
acquiring unit 310, an analyzing member 320, a display unit
340, and a respiratory function database 350. The
25　measurement data acquiring unit 310 acquires the data
measured by the measuring unit 100 and the control unit 200.

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The analyzing member 320 includes a waveform generating unit 322, a lung volume fraction calculating unit 324, a forced expiratory curve analyzing unit 326, a flow volume curve analyzing unit 328, an abdomen contribution calculating unit

5　329, a waveform characteristic extracting unit 330, a respiratory tract state judging unit 331, and a database referring unit 332. The analyzing unit 300 may function as analyzing apparatus 300 independently apart from the measuring apparatus 50. The analyzing unit 300 and the

10　analyzing apparatus 300 may be realized by an ordinary computer.

The measurement data acquiring unit 310 acquires measurement data from the control unit 200. The measurement data contains the chest data obtained by measurement of the

15　volume changes near thorax, and the abdomen data obtained by measurement of the volume changes near diaphragm. These data may be expressed by the atmospheric pressure of sensing unit 110 inside, and/or may be converted into the volume changes of the measurement part, or respiratory volume at

20　the time of breathing.

The waveform generating unit 322 generates respiratory waveform data from the measurement data which the measurement data acquiring unit 310 acquires. In this system, the respiratory waveform data is generated from the

25　chest data obtained by measurement of the volume changes near thorax, and the abdomen data obtained by measurement of

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the volume changes near diaphragm. At this time, the chest
data and the abdomen data may be weighted by the
predetermined ratio, and the respiratory waveform data may
be generated. As for the weighing ratio, it may be

5　determined according to the rate of abdomen contribution,
personal information such as sex of a subject, or the
anamneses of the subject, etc. The waveform generating unit
322 may remove the data dispersed extremely, or the portion
considered that the movement of the subject during

10　measurement might affect data when the waveform generating
unit 322 is generating the respiratory waveform data. The
respiratory waveform curve may be smoothed with a spline
function, a Bezier function, etc. When a difference is
recognized in the peak position of the chest data and the

15　abdomen data, the peak position may be adjusted to generate
the respiratory waveform data.

The lung volume fraction calculating unit 324 as an
example of the calculating unit computes the lung volume
fraction based on the respiratory waveform data generated in

20　the waveform generating unit 322. The forced expiratory
curve analyzing unit 326 as an example of the calculating
unit computes forced lung capacity, and volume of 1 second,
etc. based on the respiratory waveform data shaped by the
waveform generating unit 322. The flow volume curve

25　analyzing unit 328 as an example of the calculating unit
computes the maximum rate of the expiration flow etc. based

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on the flow volume curve which is obtained by
differentiating the forced expiratory curve. The abdomen
contribution calculating unit 329 as an example of the
calculating unit computes the abdomen contribution rate from
5　the chest data and the abdomen data. Each value may be
computed from the chest data, the abdomen data, and
respiratory waveform data, respectively. Each detailed
calculating method is explained in the explanation of the
first experiment to the fourth experiment.

10　The waveform characteristic extracting unit 330
extracts the characteristic features of the waveform of
respiratory waveform data, chest data, and/or abdomen data.
For example, such a characteristic feature that there is a
gap in the peak position of the respiratory waveform of
15　chest data and abdomen data, a feature that the peak of flow
volume curve is flat, or a feature that a flat portion
appears after the peak of flow volume curve, etc. The
waveform features which the waveform extracting unit 330
should extract may be stored beforehand, and the features of
20　the waveform may be extracted by judging whether a subject's
respiratory waveform data agree with the stored features.

The respiratory tract state judging unit 331 judges a
constriction or a blockage of a respiratory tract referring
to a respiratory waveform data, a forced expiratory curve,
25　and/or a flow volume curve. The respiratory tract state
judging unit 331 may judge that the subject's respiratory

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tract is either constricted or blocked in the case the

respiratory waveform data, the forced expiration curve, and

the flow volume curve show a waveform that reveals an

increase of inside pressure of the sensing unit 110 equipped

5   near thorax or near diaphragm, when a subject starts

exhaling. Although the waveform which shows the atmospheric

pressure in a cave decreases in connection with exhaling in

the case of a healthy person who does not have a

constriction in the respiratory tract, in the case of a

10   patient whose respiratory tract is constricted, the

phenomenon which the atmospheric pressure in the cave, i.e.,

the chest data, or abdomen data increases because of factors,

such as restriction of the air current in the constriction

portion at the time of exhaling or the abnormal movement of

15   the respiratory muscles at the time of exhaling, has been

observed by the inventors of the present invention. Since

such phenomena are characteristic of the asthmatic patients

who have conditions of the respiratory tract constriction,

the respiratory tract state judging unit 331 may judge that

20   the subject who shows such measurement results is doubtful

of having the respiratory tract constriction. The details

of the phenomena are considered based on the results of the

fifth experiment mentioned later. The respiratory tract

state judging unit 331 may judge the degree of constriction

25   or blockage of a respiratory tract based on the increasing

situation of the atmospheric pressure inside the sensing

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unit 110 at the time of exhaling. For example, when the
pressure increase is steep, the amount of pressure increase
is large, or time until the increased pressure returns is
long, the degree of a blockage of a respiratory tract is

5   high. The degree of a blockage of respiratory tract may be
judged by considering inclination of forced expiration curve,
high order differentiation coefficient, an integration value,
form, the height of a peak, etc. to be an index. The degree
of constriction or a blockage of a respiratory tract may be

10   judged with analyzing the respiratory waveform at the time
of exhaling hydrodynamically.

The database referring unit 332 acquires a medical
view based on the lung volume fraction, the forced lung
capacity, the forced expiratory volume one second, the peak

15   expiratory flow rate, the respiratory waveform, the forced
expiratory curve, a flow volume curve, and the rate of
abdomen contribution, the feature of the respiratory
waveform extracted by the waveform characteristic extracting
unit 330, etc. referring to the respiratory function

20   database 350. At this time, further information, such as
the subject's sex, age, height, weight, body fat, chest
circumference, waist size, and anamneses may be taken into
the reference.

The display unit 340 displays information, such as the

25   measured chest data, the abdomen data, and/or the
respiratory waveform data, the computed respiratory function

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barometer, and the medical view acquired from the

respiratory function database 350, on a display screen such

as a liquid crystal display.

The respiratory function database 350 stores

5 information, such as respiratory function barometers of the

lung volume fraction, the forced lung capacity, the forced

expiratory volume 1 second, the peak expiratory flow rate,

the respiratory waveform, the forced expiratory curve, the

flow volume curve, and the rate of abdomen contribution, and

10 the features of the respiratory waveform, correspondent with

the medical views. At this time, subject's sex, age, height,

weight, body fat, anamneses, etc. may be taken into

consideration. For example, the feature "the peak of a flow

volume curve is flat," and the medical view "there is a

15 doubt of constriction in upper respiratory tract" may be

saved correspondently. The medical views may not only be

the name of a respiratory disease presumed from the

measurement results, but also be the conditions of

respiratory organs, respiratory muscles, state of other

20 organs, grade of the disease, as well as a proposal of

suitable rehabilitation program and exercise, etc.

In Fig. 1, although the measuring unit 100 and the

control unit 200 are collectively shown as the measuring

apparatus 50, they do not need to be constituted in one set.

25 Moreover, each composition component may be comprised in

other units. For example, the pressurization pump 220, the

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pressure gauge 230, the recording unit 240, etc. may be placed in the measuring unit 100 side, as well as the condition input unit 290 and the display unit 270, etc. may be formed in the analyzing unit 300 side. The control unit

5　200 and the analyzing unit 300 may be constituted in one set. Thus, combinations of the components are highly flexible, which will be highly evaluated by the people concerned. The respiratory function database 350 may be installed in the external server etc., and accessed through a communication

10　means such as a network.

The measuring apparatus 50 and the analyzing apparatus 300 may be equipped in different places. At this time, the data measured by the measuring apparatus 50 may be provided to the analyzing apparatus 300 by an external memory media,

15　such as a floppy disk, CD-ROM, and MO, or through a network. Thus the measurement data can be analyzed suppose a subject lives in a doctor-less village or a depopulated area such as an isolated island and the analyzing apparatus is not available in the neighborhood. Moreover, for the measuring

20　apparatus 50 of the present embodiment, the measuring unit 100 can be equipped comparatively easily, the subject can measure by himself/herself or with the help of a family etc. If a subject owns the measuring apparatus 50 at his/her house, it also is possible for the subject to transfer the

25　measured data to a hospital and to acquire a doctor's view. Therefore, even if the subject is difficult to go out, it is

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possible for the subject to receive appropriate diagnosis

from a doctor. Moreover, for example, the grade of the

blockage situation or condition of the respiratory tract of

a patient of sleep apnea syndrome (SAS) can be diagnosed by

5　is equipped with this measuring unit 100 during sleep at a

house etc., and or measurement of the respiratory state at

the time of sleep can be made continuously.

　　When the measuring apparatus 50 of the present

embodiment is used as the rehabilitation assisting apparatus,

10　a value of a load given to a subject during rehabilitation

can be evaluated appropriately as the respiratory state in

rehabilitation can be monitored. Moreover, the respiratory

function of the subject can be inspected continuously

without removing the measuring unit 100 after the

15　rehabilitation, and the effect of the rehabilitation can be

appropriately evaluated. Furthermore, because a subject can

operate the measuring unit 100 easily by himself/herself,

he/she can perform rehabilitation even in the environment

where the assistance of a doctor or a physiotherapist cannot

20　be given. For example, a subject can perform rehabilitation

at home, and receive a diagnosis from a doctor by

transferring the measurement data during and after

rehabilitation.

　　Furthermore, the measuring apparatus 50 of the present

25　embodiment can be used not only in the medical area but also

in various places. For instance, the measuring apparatus 50

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can be equipped in a sport facility, and then a user may

enable it to check a respiratory state before exercise and

after exercise. Moreover, the respiratory state can also be

monitored during an aerobics performance. Thus, the

5   measuring system 10 and the measuring apparatus 50 of the

present embodiment are convenient to carry, and wearing and

operation are also easy, as well as they may be used by

various users in various places.

Fig. 6 schematically shows the appearance of the

10   control unit 200. A speaker as an example of the indicating

unit 260, a liquid crystal display unit as an example of the

display unit 270, an input interface 292 for inputting

conditions into the condition input unit 290, and a cable

282 for transferring the measurement data to the analyzing

15   unit 300 by the transfer unit 280 are attached at the

external surface of the control unit 200. Moreover, a tube

114 for the pressurization pump 220 to send gas inside of

the sensing unit 110 and a tube 112 for measuring the inner

pressure of the sensing unit 110 are connected.

20   Fig. 7 shows the procedure for measuring the

respiratory function using the measuring system 10 of the

present embodiment. First, a subject is equipped with the

costal respiration measuring unit 100a and the abdominal

respiration measuring unit 100b (S100). Here, in the case

25   rehabilitation is performed (Y of S102), the respiratory

function rehabilitation are carried out (S104), and the

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respiratory function inspection is followed. In the case

rehabilitation is not performed (N of S102), S104 is skipped.

Prior to the respiratory function inspection, the initial

pressurization is performed (S106) by sending gas inside of

5　the sensing unit 110 using the pressurization pump 220.

Then measurement of the respiratory function is carried out

maintaining the amount of gas inside the sensing unit 110

(S108).

Fig. 8 shows the procedure for analyzing the

10　respiratory function using the measuring system 10 of the

present embodiment. First, the measurement data acquiring

unit 310 acquires measurement data (S200). Then, the

waveform generating unit 322 generates the respiratory

waveform data from the measurement data (S202). Then, the

15　lung volume fraction calculating unit 324 computes the lung

volume fraction (S204), the forced expiration curve

analyzing unit 326 computes the forced lung capacity and the

forced expiratory volume 1 second, etc. (S206), the flow

volume curve analyzing unit 328 computes the peak expiratory

20　flow rate etc. (S208), and the abdomen contribution

calculating unit 329 computes the rate of abdomen

contribution etc. (S209). Then the waveform characteristic

extracting unit 330 extracts the characteristic features of

the respiratory waveform (S210). Furthermore, the

25　respiratory tract state judging unit 331 judges the state of

constriction or blockage of the respiratory tract with

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reference to the respiratory waveform data, the forced

expiration curve, or the flow volume curve (S211). Further

the database referring unit 332 acquires a medical view for

the subject referring to the respiratory function database

5   350 based on the data, such as the feature of the lung

volume fraction, the forced lung capacity, the peak

expiratory flow rate, the rate of abdomen contribution, and

the respiratory waveform, (S212). Finally, the analysis

result is displayed on the display unit 340 (S214).

10   In the above, the composition and operation of the

respiratory function measuring system 10 are explained. Then,

the result is shown which was obtained from the respiratory

function inspection of multiple subjects using the

respiratory function measuring system 10 of this embodiment.

15   The experiment 1 to the experiment 4 were performed to

healthy persons as subjects who did not have respiratory

function difficulties, and experiment 5 was performed to

patients as subjects who had respiratory function

difficulties. First, the experiment 1 to the experiment 3

20 . show that the respiratory function measuring system 10 of

this embodiment has function equivalent to that of the

Spirometer. Further, the experiment 4 shows that the

respiratory function measuring system 10 of this embodiment

has function equivalent to that of the respisomnogram.

25 Furthermore, the experiment 5 shows the features of the

respiratory waveforms of a patient who had respiratory

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function difficulties, and the diagnostic method was

considered to lead a medical view from the measurement

result in this system.

<Conditions of the experiment>

5   Respiratory function inspections by this system were

conducted from July 15, 2000 to November 15, 2000 to 21

healthy persons (12 men and 9 women) who did not have

respiratory function difficulties. At this time, the

measurement by the Spirometer was also performed

10   simultaneously with the measurement by this system, and both

data were compared. The subject's sex, age, height, weight,

BMI, and the rate of body fat are shown in Fig. 9. The size

of the fixing unit 120 was 140 mm x 1170 mm, the sensing

unit 110 was 125 mm x 230 mm, and the initial pressure was

15   30 mmHg for men and 20 mmHg for women. Since it was

admitted by the applicant of the present invention that the

measurement data when setting an initial pressurization

value to 30 mmHg and the value to 20 mmHg could be equally

treated without rectifying by preliminary experiment, the

20   data obtained from men and women were treated equally and

analyzed. And, the respiratory waveform data were generated

with summing the chest data and the abdomen data.

(Experiment 1) Measurement of lung volume fraction

       Fig. 10 shows change of inner pressure of the sensing

25   unit 110 with passage of time when measuring the lung volume

fraction of a subject. In the figure, a solid line shows

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the chest data which was measured by costal respiration measuring unit 100a, a thin solid line shows the abdomen data measured by abdominal respiration measuring unit 100b, and a thick solid line shows the respiratory waveform data

5　which is the sum of each data. Moreover, LV1 shows the maximum expiratory level of the respiratory waveform data, LV2 shows the resting expiratory level of the respiratory waveform data, LV3 shows the resting inspiratory level of the respiratory waveform data, and LV4 shows the maximum

10　inspiratory level of the respiratory waveform data.

(Experiment 1-1) Measurement of the vital capacity VC

The vital capacity VC is given by the difference of the maximum expiratory level LV1 and the maximum inspiratory level LV4. Since inner pressure of the sensing unit 110 is

15　not converted into the respiration volume in this experiment, the quantity computed from the measurement result shown in Fig. 10 is not the vital capacity VC itself, but it is the barometer VC1 for computing vital capacity. In the case of the subject 2, VC1 is calculated as 78.6 (mmHg) when only

20　the chest data is used, and 12.42 (mmHg) when only the abdomen data are used, and 88.32 (mmHg) when the respiratory waveform data is used. The vital capacity VC was calculated as 2.68 (1) from a result measured simultaneously with the Spirometer.

25　Similar measurement was performed to 21 subjects and the results were compared with the vital capacity VC

55

measured by the Spirometer and evaluated. By the way, as for the subjects for whom the waveform of the measurement data disordered largely, the data were not used for evaluation. The vital capacity VC1 computed from each

5 subject's respiratory waveform data is shown in Fig. 11A. Fig. 11B shows the measurement results VC1 measured by the respiratory function measuring system 10 plotted against the measurement results VC2 measured by the Spirometer. The least squares regression line is VC1 = 40.382 x VC2 - 39.646,

10 and the correlation coefficient is 0.876 which is a high value.

(Experiment 1-2) Measurement of the expiratory reserve volume ERV

The expiratory reserve volume ERV is given by the

15 difference of the maximum expiratory level LV1 and the resting expiratory level LV2. Since inner pressure of the sensing unit 110 is not converted into the respiration volume in this experiment, the quantity computed from the measurement result shown in Fig. 10 is not the expiratory

20 reserve volume ERV itself, but it is the barometer ERV1 for computing the expiratory reserve volume. In the case of the subject 2, ERV1 is calculated as 9.6 (mmHg) when only the chest data is used, and -1.12 (mmHg) when only the abdomen data are used, and 7.46 (mmHg) when the respiratory waveform

25 data is used. The expiratory reserve volume ERV was calculated as 0.99 (l) from a result measured simultaneously

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with the Spirometer.

Similar measurement was performed to 21 subjects and
the results were compared with the expiratory reserve volume
ERV2 measured by the Spirometer and evaluated. By the way,
5 as for the subjects for whom the waveform of the measurement
data disordered largely, the data were not used for
evaluation. The barometer of the expiratory reserve volume
ERV1 computed from each subject's respiratory waveform data
is shown in Fig. 12A. Fig. 12B shows the measurement
10 results ERV1 measured by the respiratory function measuring
system 10 plotted against the measurement results ERV2
measured by the Spirometer. The least squares regression
line is ERV1 = 8.3603 x ERV2 + 0.738, and the correlation
coefficient is 0.635 which is a high value.
15 (Experiment 1-3) Measurement of the inspiratory reserve
volume IRV

The inspiratory reserve volume IRV is given by the
difference of the maximum inspiratory level LV4 and the
resting inspiratory level LV3. Since inner pressure of the
20 sensing unit 110 is not converted into the respiration
volume in this experiment, the quantity computed from the
measurement result shown in Fig. 10 is not the inspiratory
reserve volume IRV itself, but it is the barometer IRV1 for
computing the inspiratory reserve volume. In the case of
25 the subject 2, IRV1 is calculated as 57.33 (mmHg) when only
the chest data is used, and 8.63 (mmHg) when only the

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abdomen data are used, and 64.25 (mmHg) when the respiratory

waveform data is used. The inspiratory reserve volume IRV

was calculated as 1.18 (1) from a result measured

simultaneously with the Spirometer.

5　　　　　Similar measurement was performed to 21 subjects and

the results were compared with the inspiratory reserve

volume IRV2 measured by the Spirometer and evaluated. By

the way, as for the subjects for whom the waveform of the

measurement data disordered largely, the data were not used

10　for evaluation. The barometer of the inspiratory reserve

volume IRV1 computed from each subject's respiratory

waveform data is shown in Fig. 13A. Fig. 13B shows the

measurement results IRV1 measured by the respiratory

function measuring system 10 plotted against the measurement

15　results IRV2 measured by the Spirometer. The least squares

regression line is IRV1 = 44.662 x IRV2 - 6.2966, and the

correlation coefficient is 0.756 which is a high value.

(Experiment 1-4) Measurement of the inspiratory capacity IC

　　　　　The inspiratory capacity IC is given by the difference

20　of the maximum inspiratory level LV4 and the resting

expiratory level LV2. Since inner pressure of the sensing

unit 110 is not converted into the respiration volume in

this experiment, the quantity computed from the measurement

result shown in Fig. 10 is not the inspiratory capacity IC

25　itself, but it is the barometer IC1 for computing the

inspiratory capacity. In the case of the subject 2, IC1 is

58

calculated as 69 (mmHg) when only the chest data is used,

and 13.63 (mmHg) when only the abdomen data are used, and

80.86 (mmHg) when the respiratory waveform data is used.

The inspiratory capacity IC was calculated as 1.69 (l) from

5　a result measured simultaneously with the Spirometer.

Similar measurement was performed to 21 subjects and

the results were compared with the inspiratory capacity IC2

measured by the Spirometer and evaluated. By the way, as

for the subjects for whom the waveform of the measurement

10　data disordered largely, the data were not used for

evaluation. The barometer of the inspiratory capacity IC1

computed from each subject's respiratory waveform data is

shown in Fig. 14A. Fig. 14B shows the measurement results

IC1 measured by the respiratory function measuring system 10

15　plotted against the measurement results IC2 measured by the

Spirometer. The least squares regression line is IC1 =

45.736 x IC2 - 13.977, and the correlation coefficient is

0.770 which is a high value.

(Experiment 1-5) Measurement of the tidal volume TV

20　　The tidal volume TV is given by the difference of the

resting inspiratory level LV3 and the resting expiratory

level LV2. Since inner pressure of the sensing unit 110 is

not converted into the respiration volume in this experiment,

the quantity computed from the measurement result shown in

25　Fig. 10 is not the tidal volume TV itself, but it is the

barometer TV1 for computing the tidal volume. In the case

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of the subject 2, TV1 is calculated as 11.67 (mmHg) when

only the chest data is used, and 4.99 (mmHg) when only the

abdomen data are used, and 16.61 (mmHg) when the respiratory

waveform data is used. The tidal volume TV was calculated

5   as 0.51 (1) from a result measured simultaneously with the

Spirometer.

Similar measurement was performed to 21 subjects and

the results were compared with the tidal volume TV2 measured

by the Spirometer and evaluated. By the way, as for the

10   subjects for whom the waveform of the measurement data

disordered largely, the data were not used for evaluation.

The barometer of the tidal volume TV1 computed from each

subject's respiratory waveform data is shown in Fig. 15A.

Fig. 15B shows the measurement results TV1 measured by the

15   respiratory function measuring system 10 plotted against the

measurement results TV2 measured by the Spirometer. The

least squares regression line is TV1 = 18.5 x TV2 + 12.745,

and the correlation coefficient is 0.541 which is a high

value.

20   From above results, it has been confirmed that the

lung volume fraction can be measured by the respiratory

function measuring system 10 as well as by the Spirometer.

Moreover, the absolute value of the lung volume fraction can

be obtained from the measurement data of this system using

25   the formula of regression line. The conversion formula with

high accuracy can be obtained by performing the same

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measurement to more subjects.

(Experiment 2) Measurement of the forced expiratory curve

Fig. 16 shows change of inner pressure of the sensing

unit 110 with time when measuring the forced expiratory

5　curve of the subject 2. In the figure, a solid line shows

the chest data measured by the costal respiration measuring

unit 100a, a thin solid line shows the abdomen data measured

by the abdominal respiration measuring unit 100b and a thick

line shows the respiratory waveform data which is the sum of

10　the each data. Fig. 17A, 17B, and 17C are the flow volume

curves obtained by differentiating the forced expiration

curve of Fig. 16. Fig. 17A shows the flow volume curve

obtained from the abdomen data, Fig. 17B shows the flow

volume curve obtained from the chest data, and Fig. 17C

15　shows the flow volume curve obtained from the respiratory

waveform data. Generally, the flow volume curve obtained by

the Spirometer is represented with the respiratory volume on

a horizontal axis and respiratory rate on a vertical axis,

but in Fig. 17, the time on the horizontal axis. This is

20　because the data was analyzed without converting them into

the respiratory volume, but It is considered that there is

no influence in calculation of the peak expiratory flow rate

PEFR.

(Experiment 2-1) Measurement of the forced vital capacity

25　FVC

The forced vital capacity FVC is given by a method

61

shown in Fig. 16. Since inner pressure of the sensing unit

110 is not converted into the respiration volume in this

experiment, the quantity computed from the measurement

result shown in Fig. 16 is not the forced vital capacity FVC

5   itself, but it is the barometer FVC1 for computing the

forced vital capacity. In the case of the subject 2, FVC1

is calculated as 75.8 (mmHg) when only the chest data is

used, and 11.62 (mmHg) when only the abdomen data are used,

and 83.32 (mmHg) when the respiratory waveform data is used.

10   The forced vital capacity FVC was calculated as 2.57 (1)

from a result measured simultaneously with the Spirometer.

Similar measurement was performed to 21 subjects and

the results were compared with the forced vital capacity FVC

measured by the Spirometer and evaluated. By the way, as

15   for the subjects for whom the waveform of the measurement

data disordered largely, the data were not used for

evaluation. The barometer of the forced vital capacity FVC1

computed from each subject's respiratory waveform data is

shown in Fig. 18A. Fig. 18B shows the measurement results

20   FVC1 measured by the respiratory function measuring system

10 plotted against the measurement results FVC2 measured by

the Spirometer. The least squares regression line is FVC1 =

33.874 x FVC2 - 33.682, and the correlation coefficient is

0.831 which is a high value.

25   (Experiment 2-2) Measurement of the forced expiratory volume

in one second FEV1.0

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The forced expiratory volume in one second FEV1.0 is

given by a method shown in Fig. 16. Since inner pressure of

the sensing unit 110 is not converted into the respiration

volume in this experiment, the quantity computed from the

5　measurement result shown in Fig. 16 is not the forced

expiratory volume in one second FEV1.0 itself, but it is the

barometer FEV1.01 for computing the forced expiratory volume

in one second. In the case of the subject 2, FEV1.01 is

calculated as 75.6 (mmHg) when only the chest data is used,

10　and 10.16 (mmHg) when only the abdomen data are used, and

82.84 (mmHg) when the respiratory waveform data is used.

The forced expiratory volume in one second FEV1.0 was

calculated as 2.51 (1) from a result measured simultaneously

with the Spirometer.

15　　　　Similar measurement was performed to 21 subjects and

the results were compared with the forced expiratory volume

in one second FEV1.0 measured by the Spirometer and

evaluated. By the way, as for the subjects for whom the

waveform of the measurement data disordered largely, the

20　data were not used for evaluation. The barometer of the

forced expiratory volume in one second FEV1.01 computed from

each subject's respiratory waveform data is shown in Fig.

18A. Fig. 18B shows the measurement results FEV1.01

measured by the respiratory function measuring system 10

25　plotted against the measurement results FEV1.02 measured by

the Spirometer. The least squares regression line is

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FEV1.01 = 38.438 x FEV1.02 - 39.038, and the correlation

coefficient is 0.790 which is a high value.

(Experiment 2-3) Measurement of the peak expiratory flow

rate PEFR

5   The peak expiratory flow rate PEFR is given by a

method shown in Fig. 17. Since inner pressure of the

sensing unit 110 is not converted into the respiration

volume in this experiment, the quantity computed from the

measurement result shown in Fig. 16 is not the peak

10   expiratory flow rate PEFR itself, but it is the barometer

PEFR1 for computing the peak expiratory flow rate. In the

case of the subject 2, PEFR1 is calculated as 8.65 (mmHg/s)

when only the chest data is used, and 1.51 (mmHg/s) when

only the abdomen data are used, and 9.69 (mmHg/s) when the

15   respiratory waveform data is used. The peak expiratory flow

rate PEFR was calculated as 7 (1/s) from a result measured

simultaneously with the Spirometer.

Similar measurement was performed to 21 subjects and

the results were compared with the peak expiratory flow rate

20   PEFR measured by the Spirometer and evaluated. By the way,

as for the subjects for whom the waveform of the measurement

data disordered largely, the data were not used for

evaluation. The barometer of the peak expiratory flow rate

PEFR1 computed from each subject's respiratory waveform data

25   is shown in Fig. 20A. Fig. 20B shows the measurement

results PEFR1 measured by the respiratory function measuring

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system 10 plotted against the measurement results PEFR2
measured by the Spirometer. The least squares regression
line is PEFR1 = 1.8788 x PEFR2 - 5.7519, and the correlation
coefficient is 0.845 which is a high value.

5　　　　From above results, it has been confirmed that the
forced vital capacity, the forced expiratory volume in one
second, the peak expiratory flow rate, the forced expiratory
curve, and the flow volume curve, etc. can be measured by
the respiratory function measuring system 10 as well as by
10　the Spirometer. Moreover, the absolute values of above data
can be obtained in the same way of the lung volume fraction
from the measurement data of this system using the formula
of the regression line. The conversion formula with high
accuracy can be obtained by performing the same measurement
15　to more subjects.

(Experiment 3) Measurement of the resting ventilation volume
　　　　Fig. 21 shows change of inner pressure of the sensing
unit 110 with time when measuring the resting ventilation
volume of the subject 2. In the figure, a solid line shows
20　the chest data measured by the costal respiration measuring
unit 100a, a thin solid line shows the abdomen data measured
by the abdominal respiration measuring unit 100b and a thick
line shows the respiratory waveform data which is the sum of
the each data.

25　(Experiment 3-1) Measurement of the minutes volume MV
　　　　The minutes volume MV represents the ventilation

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volume of one minute, and is calculated by multiplying the one-time ventilation volume by the frequency of the respiration in one minute. Since inner pressure of the sensing unit 110 is not converted into the respiration

5 volume in this experiment, the quantity computed from the measurement result shown in Fig. 21 is not the minutes volume MV itself, but it is the barometer MV1 for computing the minutes volume. In the case of the subject 2, MV1 is calculated as 175.34 (mmHg) when only the chest data is used,

10 and 91.59 (mmHg) when only the abdomen data are used, and 278 (mmHg) when the respiratory waveform data is used. The minutes volume MV was calculated as 4.66 (1) from a result measured simultaneously with the Spirometer.

Similar measurement was performed to 21 subjects and

15 the results were compared with the minutes volume MV measured by the Spirometer and evaluated. By the way, as for the subjects for whom the waveform of the measurement data disordered largely, the data were not used for evaluation. The barometer of the minutes volume MV1

20 computed from each subject's respiratory waveform data is shown in Fig. 22A. Fig. 22B shows the measurement results MV1 measured by the respiratory function measuring system 10 plotted against the measurement results MV2 measured by the Spirometer. The least squares regression line is MV1 =

25 35.675 x MV2 + 89.158, and the correlation coefficient is 0.755 which is a high value.

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(Experiment 3-2) Measurement of the tidal volume TV

　　The tidal volume TV is calculated by averaging the differences between the peaks and the valleys of the respiratory waveform at resting. Since inner
5　pressure of the sensing unit 110 is not converted into the respiration volume in this experiment, the quantity computed from the measurement result shown in Fig. 21 is not the tidal volume TV itself, but it is the barometer TV1 for computing the tidal volume. In the case of the subject 2,
10　TV1 is calculated as 11.99 (mmHg) when only the chest data is used, and 6.25 (mmHg) when only the abdomen data are used, and 18.18 (mmHg) when the respiratory waveform data is used. The tidal volume TV was calculated as 0.33 (1) from a result measured simultaneously with the Spirometer.

15　　Similar measurement was performed to 21 subjects and the results were compared with the tidal volume TV measured by the Spirometer and evaluated. By the way, as for the subjects for whom the waveform of the measurement data disordered largely, the data were not used for evaluation.
20　The barometer of the tidal volume TV1 computed from each subject's respiratory waveform data is shown in Fig. 23A. Fig. 23B shows the measurement results TV1 measured by the respiratory function measuring system 10 plotted against the measurement results TV2 measured by the Spirometer. The
25　least squares regression line is TV1 = 35.01 x TV2 + 5.1348, and the correlation coefficient is 0.649 which is a high

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value.

(Experiment 3-3) Measurement of the interval of the waveform
RR

The interval of the waveform RR is calculated by

5   averaging the intervals between the peaks of the respiratory

waveform at resting but in this experiment the reciprocal

thereof is calculated as the frequency of the respiration

per one minute. In the case of the subject 2, RR1 is

calculated as 13.97 (/min) when only the chest data is used,

10   and 13.98 (/min) when only the abdomen data are used, and 14

(/min) when the respiratory waveform data is used. The

interval of the waveform RR was calculated as 14.12 (/min)

from a result measured simultaneously with the Spirometer.

Similar measurement was performed to 21 subjects and

15   the results were compared with the interval of the waveform

RR measured by the Spirometer and evaluated. By the way, as

for the subjects for whom the waveform of the measurement

data disordered largely, the data were not used for

evaluation. The barometer of the interval of the waveform

20   RR1 computed from each subject's respiratory waveform data

is shown in Fig. 24A. Fig. 24B shows the measurement

results RR1 measured by the respiratory function measuring

system 10 plotted against the measurement results RR2

measured by the Spirometer. The least squares regression

25   line is RR1 = 1.0003 x RR2 - 0.4108, and the correlation

coefficient is 0.997 which is a high value.

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From above results, it has been confirmed that the
resting ventilation minute volume, the tidal volume, and the
rate of the respiratory waveform etc. can be measured by the
respiratory function measuring system 10 as well as by the

5　Spirometer. Moreover, the absolute values of above data can
be obtained in the same way of the lung volume fraction from
the measurement data of this system using the formula of the
regression line. The conversion formula with high accuracy
can be obtained by performing the same measurement to more

10　subjects.

As mentioned above, it has been confirmed that the
data equivalent to those by Spirometer were obtained by this
system. However, the advantage of this system does not
remain in it, but this system has another big advantage that

15　the chest data and the abdomen data can be measured
independently. Below, the relation between the chest data
and the abdomen data is explained.
(Experiment 4) Relation between the chest data and the
abdomen data

20　　The relation of the chest data and abdomen data in the
above-mentioned experiment was evaluated. Below, the
measurement data at a time of resting and the measurement
data at a time of being forced expiration are shown.
(Experiment 4-1) Relation between the chest data and the

25　abdomen data at a time of resting

Fig. 25 shows the relation between the chest data and

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the abdomen data when the resting ventilation volume was measured in experiment 3. In Fig. 25, the chest data is expressed on the horizontal axis and the abdomen data is expressed on the vertical axis. Regressing them in a

5　straight line by the least-squares method, (abdomen data) = 0.4625 x (chest data) + 4.5258, and the correlation coefficient showed 0.940 which is a high numerical value. This means that the subject had little variation in breathing at a time of resting, and that the costal

10　respiration and the abdominal respiration were performed in an approximately same ratio.

(Experiment 4-2) Relation between the chest data and the abdomen data at a time of being forced expiration

Fig. 26 shows the relation of the chest data and the

15　abdomen data when the forced expiration curve was measured in experiment 2. In Fig. 26, the chest data is expressed on the horizontal axis and the abdomen data is expressed on the vertical axis. Regressing them in a straight line by the least-squares method, (abdomen data) = 0.1462 x (chest data)

20　+ 12.614, and the correlation coefficient was 0.871. Since the gradient of the regressing straight line is decreasing compared with that at a time of resting, it is found that the predominancy of the costal respiration at a time of being forced is stronger than that at a time of resting.

25　As mentioned above, it has been confirmed that the measuring system 10 of this embodiment can measure the chest

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data and the abdomen data independently, and the respiration

predominancy and the rate of abdomen contribution can be

evaluated as well as the respisomnogram. Furthermore,

although the absolute value of the data obtained by the

5   respisomnogram was not reliable and the quantitative

discussion can not be done, in this system the reliable data

can be obtained quantitatively as shown by explanation of

experiments 1-3. Thereby, comparison examination can be

quantitatively performed regarding multiple measurements of

10   the same subject and multiple subjects' measurement.

As mentioned above, it has been shown that functions

of the measurement system 10 of this embodiment are

equivalent to those of the Spirometer and the respisomnogram

by the experiments 1-4. The measurement system 10 of this

15   embodiment has not only the functions of the both apparatus

of the Spirometer and the respisomnogram, but also the

measurement system 10 of this embodiment can obtain the

information with one measurement which had to be

conventionally acquired separately in the case of the

20   spirometer and the respisomnogram. Moreover, this

measurement system can provide a medical view by measuring

the chest data and the abdomen data independently, which is

not possible with the conventional the Spirometer and the

respisomnogram.

25   For example, in the case of a patient whose upper leaf

of lung was excised because of a disease such as emphysema,

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the respiratory muscles in the breast hardly contribute to breathing, and the patient almost breathes by the abdominal respiration, but the spirometer cannot acquire this view. Although it can be known that the abdominal respiration is

5　predominant by the respisomnogram, the quantitative evaluation is difficult to be made since it lacks in reproducibility. However, since the measurement system 10 of this embodiment can acquire the data of costal respiration and abdominal respiration independently with

10　sufficient reproducibility, progresses after an operation and/or the effect of rehabilitation or medicine etc can be observed and evaluated quantitatively, which is extremely meaningful medically.

　　Moreover, for an ALS patient (Amyotrophic Lateral

15　Sclerosis) the degree of advancement of paralysis of the respiratory muscle which contributes to the costal respiration is observable by the measurement system 10 of this embodiment. In this case, the measurement system of this embodiment can also perform quantitative evaluation

20　with higher reproducibility and higher reliability compared with the conventional respisomnogram.

(Experiment 5) Measurement of patients as subjects who had respiratory disease

25　　The respiratory function measurement by this system and the spirometer was performed similar to experiments 1-4

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with making respiratory disease patients as subjects. The measurement was performed five times for each of 10 respiratory disease patients, respectively. As for the subjects for whom the waveform of the measurement data

5　disordered largely, the data were not used for evaluation. The measurement results shown in Fig. 27 to 36 were analyzed like experiments 1-3 using the total value of the chest data and the abdomen data. The graph which describes the correlation with the spirometer is shown in the same scale

10　with those of the experiments 1-3 for which the healthy persons were subjects.

　　Fig. 27A shows the measurement result of the vital capacity VC, and Fig. 27B shows the correlation with data by spirometer. Fig. 28A shows the measurement result of the

15　expiratory reserve volume ERV, and Fig. 28B shows the correlation with data by spirometer. Fig. 29A shows the measurement result of the inspiratory reserve volume IRV, and Fig. 29B shows the correlation with data by spirometer. Fig. 30A shows the measurement result the inspiratory

20　capacity IC, and Fig. 30B shows the correlation with data by spirometer. Fig. 31A shows the measurement result of tidal volume TV, and Fig. 31B shows the correlation with data by spirometer. Fig. 32A shows the measurement result of the forced expiratory volume FVC, and Fig. 32B shows the

25　correlation with data by spirometer. Fig. 33A shows the measurement result of the peak expiratory flow rate PEFR,

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and Fig. 33B shows the correlation with data by spirometer.

Fig. 34A shows the measurement result of the resting

ventilation minute volume MV, and Fig. 34B shows the

correlation with data by spirometer. Fig. 35A shows the

5　measurement result of tidal volume TV, and Fig. 35B shows

the correlation with data by spirometer. Fig. 36A shows the

measurement result of the respiratory rate RR, and Fig. 36B

shows the correlation with data by spirometer.

From the above measurement results, it is shown that

10　various kinds of respiratory function measurement can be

performed by the measurement system of this embodiment also

to respiratory disease patients. Moreover, we performed

multiple measurements for each subject, and have confirmed

that it was possible to obtain the highly reproducible

15　measurement results.

Fig. 37 shows change of inner pressure inside the

sensing unit 110 with passage of time when measuring a

certain respiratory disease patient's forced expiration

curve. The solid line shows the chest data measured by

20　costal respiratory measuring unit 100a, the thin solid line

shows the abdomen data measured by abdominal respiratory

measuring unit 100b, and the thick solid line shows the

respiratory waveform data which is the sum of the chest data

and the abdomen data. It is shown that the inner pressure

25　went up rapidly at the moment of the forced expiration after

the subject performed a maximum inspiration. This rapid

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rise of inner pressure is considered for the reason of

constriction of the respiratory tract because; it was

observed at the time of measurement of the forced expiration

curve, it was often observed for asthmatic patients, but

5 hardly observed for patients of bronchiectasis, and the

pressure rises rapidly at the moment of a forced expiration,

etc. Namely, it is considered that the inner pressure of

the sensing unit 110 went up, since the air current was

restricted in the constriction area of the respiratory tract

10 or the respiratory muscle worked differently than that of a

healthy person, when the subject tried to exhale at a blast

right after inhalation.

Fig. 38 shows the flow volume curve of a certain

respiratory disease patient as a subject. Unlike the flow

15 volume curve of a healthy person shown in Fig. 17, a big

peak is seen in the positive direction. This is considered

to reflect the rapid rise of inner pressure at the time of

forced expiration mentioned above.

Fig. 39 is a figure showing the relation between the

20 inner pressure rising value at the time of forced expiration,

and the peak expiration flow rate PEFR. The inner pressure

rise value at the time of forced expiration, which was

observed when the forced expiration curve was measured for

respiratory disease patients as subjects, shows a negative

25 correlation, and it is indicated that the rise of pressure

is reflecting the degree of constriction or blockage of a

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respiratory tract. From the above measurement results, it
is shown that this system is effective to diagnose the state
of constriction or blockage of a respiratory tract.

　　　Fig. 40 shows a structure of an analyzing server 400
5　and a terminal 500 which accesses the analyzing server 400
according to this embodiment. The analyzing server 400
receives an analysis request from the terminal 500 which is
installed in the hospital for example, through the Internet
600, and refers it to the respiratory function database 350
10　based on the received measurement data, and then transmits
the analysis result to the terminal 500. The Internet 600
is mentioned as an example of the network in this
embodiment , but it may be the networks of a cable or radio
such as a cellular-phone network, a public network, etc.

15　　　The analyzing server 400 includes a communicating unit
410 for communicating with the terminal 500 through the
Internet 600, a receiving unit 430 which receives the
request for referring to the database through the network,
an authenticating unit 440 which authenticates a user who
20　refers to the database, the measurement data acquiring unit
310, the analyzing member 320, the respiratory function
database 350, and a transmitting unit 420 for transmitting
analysis results such as a medical view to the terminal 500.
The same mark is given to what has a function equivalent to
25　the composition shown in Fig. 1 among the composition of the
analyzing server 400.

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　　　　The analyzing server 400 first authenticates whether
the user is a permitted user for the reference of the
database by the authenticating unit 440 when a reference
request of the database is received by the receiving unit

5　430 through the Internet 600. Then when the user is
authenticated, the measurement data acquiring unit 310
receives the chest data and the abdomen data like the
analyzing unit 300 shown in Fig. 1, and the respiratory
waveform data is generated by the waveform generating unit

10　322, the waveform characteristics of the chest data, the
abdomen data, and the respiratory waveform data is extracted
by the extracting unit 330, and the constriction state of a
respiratory tract is judged by the respiratory tract state
judging part 331, and then the medical view is acquired by

15　referring the respiratory function database 350 by the
database referring unit 332. The acquired medical view is
transmitted to a user through the Internet 600 from the
transmitting unit 420. Further, an accounting unit may be
attached to charge the user who refers to the database.

20　　　　The analyzing server 400 shown in Fig. 40 provides
mainly the reference service with managing the respiratory
function database 350, and the composition such as the lung
capacity fraction calculating unit 324 etc. is omitted, but
of course the analyzing server 400 may include these

25　compositions. The composition such as the lung capacity
calculating unit 324 may be added to the terminal 500 side.

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In this case, the measurement data acquiring unit 310 may acquire the respiratory function barometers, such as the lung capacity fraction, from the terminal 500.

The terminal 500 includes a measurement data
5　transmitting unit 520 for transmitting data which the measuring apparatus 50 measures to the analyzing server 400, a communicating unit 510 for communicating with the analyzing server 400 through the internet 600, an analysis result acquiring unit 530 for acquiring the analysis result
10　from the analyzing server 400, and the display unit 340 which displays the analysis result at the display apparatus.

Thus, a service for analyzing the respiratory function can be provided to more users by providing a function equivalent to the analyzing unit 300 in Fig. 1 as the server.
15　Moreover, the maintenance such as a renewal and/or modification of the database can be made easily by managing the respiratory function database 350 at the analyzing server 400 in the block without placing them at each terminal 500.

20　Fig. 41A, 41B, 41C, 41D, and 41E show examples how to use a rehabilitation assisting apparatus according to the embodiment. The rehabilitation assisting apparatus has the same composition as the measuring apparatus 50 shown in Fig. 1, and the measuring unit 100 is used as a pressurizing unit
25　and the sensing unit 110 is used as the pressurizing member.

Fig. 41A shows how the upper leaf of the subject's

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lung is squeezed with the pressurizing unit 100. At this
time, the pressurizing unit 110 is fixed in the area above
the 4th rib, and gas is sent inside the pressurizing unit
110 to become the predetermined pressure by the pressurizing
5　pump, so that the expectoration part is squeezed. Fig. 41B
and 41C show how the middle part of a subject's lung is
squeezed with the pressurizing unit 100. The right side of
the lung is squeezed in Fig. 41B and the right side in Fig
41C. Fig. 41D shows how the lower leaf of a subject's lung
10　is squeezed with the pressurizing unit 100. Fig. 41E shows
how the rear bottom side of a subject's lung is squeezed
with the pressurizing unit 100. To squeeze appropriate part,
multiple pressurizing units 100 may be equipped, and/or the
pressurizing unit 100 may be attached with multiple
15　pressurizing parts 110, if needed.

　　　　Fig. 42 shows the procedure of a rehabilitation
assisting method according to the embodiment. First, the
subject is equipped with the pressurizing unit 100 as shown
in Fig. 41 (S300). Then gas is sent into the inside of the
20　pressurizing unit 110, so that the expectoration part is
squeezed (S302). At this time, the subject's respiratory
state is measured simultaneously with the change of the
atmospheric pressure of the pressurizing unit 110 inside
(S304). Whether the pressure of pressurizing unit 110
25　inside is suitable is evaluated while the subject's
respiratory state is observed, and the pressurization value

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may be changed if required (S306). The procedure is continued to N of S308 until the rehabilitation is completed, and the rehabilitation step is carried out. After the rehabilitation is completed (Y of S308), in order to measure

5　a subject's respiratory state, the atmospheric pressure of pressurizing unit 110 inside is set at a suitable initial pressure (S310). Then, the respiratory function measurement is carried out (S312), and the effect of the rehabilitation is evaluated (S314).

10　　　Thus, the effect of the rehabilitation is evaluated since the rehabilitation assisting apparatus according to the embodiment also has the function as the measuring apparatus, and can measure the respiratory function during and after the rehabilitation. In the above-mentioned

15　explanation, squeezing method was introduced as the physiotherapy, but rehabilitation and respiratory function measurement can be similarly performed when applying other method.

　　　Although the present invention has been described by

20　way of exemplary embodiments, it should be understood that many changes and substitutions may further be made by those skilled in the art without departing from the scope of the present invention which is defined by the appended claims.

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